

# Building a Distributed Decision Support System Architecture for National Health Care

Sinyinda Muwanei, Douglas Kunda, Gilbert Sibajene

**Abstract—** There are several benefits for developing a distributed decision support system for national health care. Decision makers especially in the health sector of the nation will make timely, informative and accurate decisions as both detailed and aggregated data from different health centres or facilities in the nation will be at their disposal together with various tools for analysis of data. The paper describes the architecture and prototype of distributed decision support system for national health care.

**Index Terms—** Distributed Systems , Decision Support, Datawarehouse, Middleware,ETL

## I. INTRODUCTION

The healthcare sector is one of the largest sectors in every nation, catering to thousands of people on a regular basis. Patients receive medical treatment from health facilities. Nowadays, in most hospitals the health data is distributed across several heterogeneous and autonomous information systems whose interconnection is difficult to achieve. Integration of such system may bring about many advantages [1]. The accumulation of this information is beneficial both for subsequent treatment of same patients as well as statistical analysis by health management authorities of nation. This accumulated information hence needs to be securely and accurately stored for future analysis. This information at various health facilities is stored in online transactional processing systems. These transaction processing systems are not meant for analysis purposes. Therefore various what if scenario queries are not adequately catered for. Further each of these systems of various health facilities are independent of each other. The only viable solution is to use the data warehouse as the repository of detailed data from all the health facilities and using concepts of distributed systems to integrate these transactional systems with the data warehouse repository.

## II. TECHNOLOGIES FOR DECISION SUPPORT SYSTEMS

Developing a National Distributed Decision support health care system requires the use of various technologies. These are data warehousing for storage of detailed and aggregated data and distributed systems.

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### 2.1 Data Warehouses

According to bill inmon a dataware house is a “subject-oriented, integrated, time variant and non-volatile collection of data in support of management’s decision making process” [2]. Data Warehouses (DW) systems represent a single source of information through which to analyze the status and the development of an organization [11]

Several other authors attempted to provide functional definitions for data warehouse. According to paulraj ponniah “The data warehouse is an informational environment that

- Provides an integrated and total view of the enterprise
- Makes the enterprise’s current and historical information easily available for decision making
- Makes decision-support transactions possible without hindering operational systems
- Renders the organization’s information consistent
- Presents a flexible and interactive source of strategic information” [3].

According to Ralph Kimball “a data warehouse is a system that extracts, cleans, conforms, and delivers source data into a dimensional data store and then supports and implements querying and analysis for the purpose of decision making”. [4]

Traditionally, data warehouses (DW) have been counted among the most powerful problem-solving tools to enable easy access to information and enhance the effectiveness of decision-making processes[10].

Data warehouses are extensively used in various fields that include financial institutions, insurance, health and education. Over time there has been accumulation of data in online transaction processing systems and this data now has to be used to the benefit of organization. The greatest benefit is decision making. Top management of organization would make decisions not based on experience or intuition but based on analysis of accurate accumulated data in there information systems. Operational information systems are not developed to enable complex analysis but rather transaction processing with very limited analysis. Hence the need for a data warehouse that would be used sorely for analysis.

There are various data base management systems that that data warehousing. The notable ones are Mssql Server and Oracle. In this prototype presented in this paper, Oracle 11g has been chosen as the target database management system.

### 2.2 Distributed Systems

According to Coulouris and Dollimore “a distributed system is one in which components located at networked computers communicate and coordinate their actions only by passing messages”[5].

According to Ajay D. Kshemkalyani and Mukesh Singhal a distributed system is a collection of independent entities that cooperate to solve a problem that cannot be individually solved and the motivation for using a distributed system is some or all of the following requirements:

- **Inherently distributed computations** In many applications that require reaching consensus among parties that are geographically distant, the computation is inherently distributed.
- **Resource sharing** Resources such as peripherals, complete data sets in databases, special libraries, as well as data (variable/files) cannot be fully replicated at all the sites because it is often neither practical nor cost-effective. Further, they cannot be placed at a single site because access to that site might prove to be a bottleneck.
- **Access to geographically remote data and resources** In many scenarios, the data cannot be replicated at every site participating in the distributed execution because it may be too large or too sensitive to be replicated. For example, payroll data within a multinational corporation is both too large and too sensitive to be replicated at every branch office/site. It is therefore stored at a central server which can be queried by branch offices. Similarly, special resources such as supercomputers exist only in certain locations, and to access such supercomputers, users need to log in remotely. Advances in the design of resource-constrained mobile devices as well as in the wireless technology with which these devices communicate have given further impetus to the importance of distributed protocols and middleware.
- **Enhanced reliability** A distributed system has the inherent potential to provide increased reliability because of the possibility of replicating resources and executions, as well as the reality that geographically distributed resources are not likely to crash/malfunction at the same time under normal circumstances.
- **Scalability** As the processors are usually connected by a wide-area network, adding more processors does not pose a direct bottleneck for the communication network.[6]

The choice of distributed computing for the national health care decision support is ideal due to the above requirements that distributed systems achieve. The various components that are heterogenous in nature will require a middle ware layer for the sake of interoperability. Large-scale distributed systems, such as e-healthcare systems, are difficult to develop due to their complex and decentralized nature. The Service Oriented Architecture facilitates the development of such systems by supporting modular design, application integration and interoperation, and software reuse. With open standards, such as XML, SOAP, WSDL and UDDI, the Service Oriented Architecture supports interoperability between services operating on different platforms and between applications implemented in different programming languages [7].

There are various programming languages that could be used for distributed computing. The most notable ones are java, cSharp and php. Java will be used for this prototype and has been chosen due to its features that favour distributed computing.

## 1. Architecture and Implementation of national health care decision support system

### 1.1 Data warehouse Design

### 1.2 An Entity Relationship Diagram is a diagrammatic view of all the database due to be developed.

The Entity Relationship Diagram below represents the database schema that lies at each respective health centre or clinic scattered across the country.

The OLTP databases found at all health centres or clinics will hold detailed data for patients, conditions , appointments, diagnosis , doctors , treatments as well as health care centres.

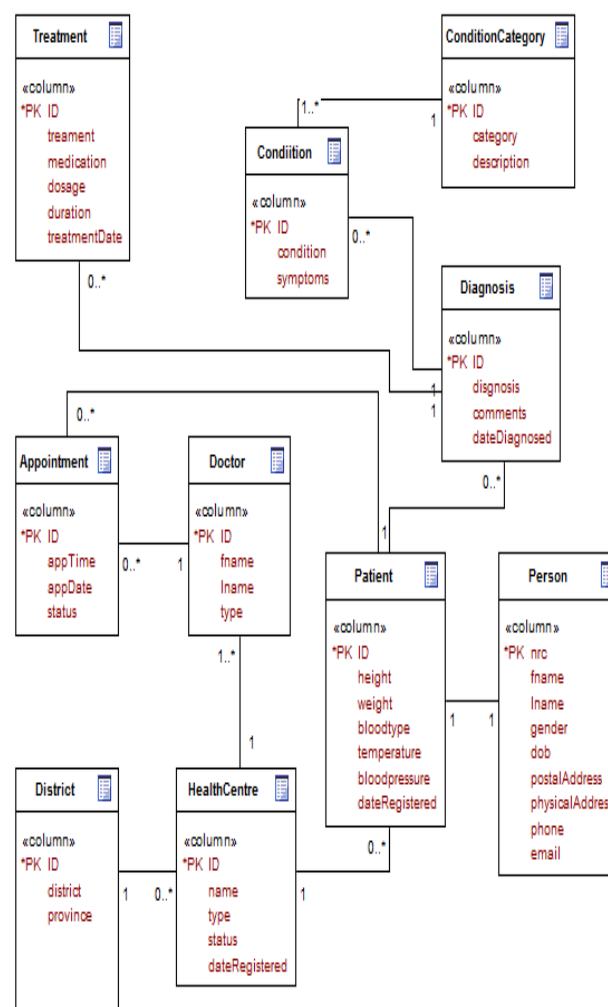


Figure 1 Entity relationship diagram

After resolving all cardinalities and constraints of the entities and relationships in the above diagram relational schema is produced. These tables show the final database structure in every health facility or clinic nation wide that will be repository of operational data.

|             |                         |
|-------------|-------------------------|
| Person      | NRC(Primary key)        |
|             | Fname                   |
|             | Lname                   |
|             | Gender                  |
|             | DoB                     |
|             | postalAddress           |
|             | physicalAddress         |
|             | Phone                   |
|             | Email                   |
|             |                         |
| Patient     | ID(primary key)         |
|             | NRC(foreign key)        |
|             | Height                  |
|             | Weight                  |
|             | Bloodtype               |
|             | Temperature             |
|             | Bloodpressure           |
|             | dateRegistered          |
|             | HCCID(foreign key)      |
|             |                         |
| Treatment   | ID(primary key)         |
|             | Treatment               |
|             | Medication              |
|             | Dosage                  |
|             | Duration                |
| Doctor      | ID(primary key)         |
|             | Fname                   |
|             | Lname                   |
|             | Type                    |
|             | HCCID(foreign key)      |
| Appointment | ID(primary key)         |
|             | AppTime                 |
|             | AppDate                 |
|             | Status                  |
|             | patientID(foreign key)  |
|             | doctorID(foreign key)   |
| Diagnosis   | ID(primary key)         |
|             | Diagnosis               |
|             | Comment                 |
|             | PatientID(foreign key)  |
|             | Datediagnosed           |
| Condition   | ID(primary key)         |
|             | Condition               |
|             | Symptom                 |
|             | categoryID(foreign key) |

Table 1

The data warehouse for the decision support system that will be used for online analytical processing will be held at the headquarters of health ministry or branch in the country. Data from all the OLTP databases in each clinic or health center nationwide would be extracted, cleaned and loaded into datawarehouse at the headquarters. The Data warehouse structure is generally represented with the help of the multi-dimensional schema which formulates information as facts and dimensions[13]. The star schema design is the chosen multi-dimensional schema and is derived from the entity relationship diagram above.

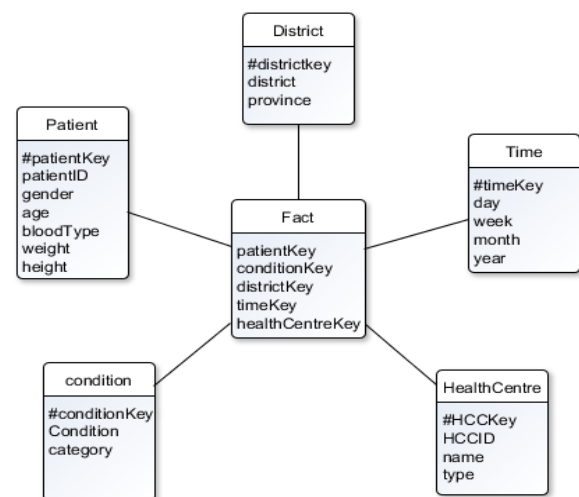


Figure 2 Star schema

| Table         | Attribute       |
|---------------|-----------------|
| Health Center | ID(primary key) |
|               | Name            |
|               | districtID      |
|               | Status          |
|               | Type            |
|               | dateRegistered  |
| District      | ID(primary key) |
|               | district        |
|               | Province        |
| Fact          | Patientkey      |
|               | Districtkey     |
|               | Healthcentrekey |
|               | Conditionkey    |
|               | Timekey         |
| Time          | Key             |
|               | Date            |
|               | Days            |
|               | Weeks           |
|               | Month           |
|               | Year            |
| Patient       | Key             |
|               | patientID       |
|               | Height          |
|               | Weight          |
|               | Bloodtype       |
|               | Age             |
|               | gender          |
|               | dateRegistered  |
|               |                 |
| Condition     | Key             |
|               | conditionID     |
|               | Condition       |
|               | category        |

Table 2: Data warehousing Tables

### III. EXTRACTION, TRANSFORMATION AND LOADING DESIGN

The Extraction, Transformation and Loading(E.T.L) procedure described in figure 3 below performs its extraction using an online procedure, also instead of flat files it directly runs a query on all participating databases by using multiples selects and appending them with the UNION keyword of SQL

data manipulation language. After extracting data into the single staging area, the transformation procedure carries out a series of validation checks and updates or deletes records that do not satisfy this. The transformation of data also includes an aggregation process[8].The loading procedure is a series of “INSERT \*/APPEND\*/ AS SELECT” statements to insert into the Dimensions. After the ETL processes are completed the analytical processes may begin. OLAP is meant to provide quality information to the end user by allowing the user to navigate through the dimensions of the data warehouse[9].

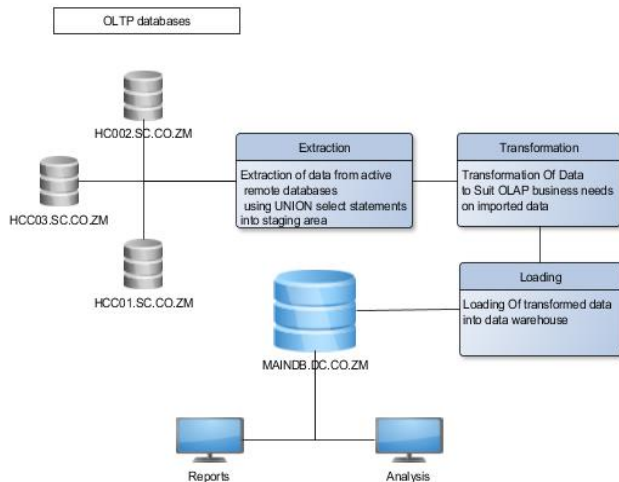


Figure 3 Extraction, transformation and loading diagram

## 3.2 Application Design and Development

The distributed application described in this paper has adopted the façade design pattern as the pattern of choice and based on the pattern are several interfaces that have been developed and relevant functionality exposed which also helps in maintenance of security in the system. Due to the fact that this is a heterogeneous distributed decision support system, a way of masking the differences in technologies is achieved by usage of web services. A number of business, data access object and façade classes which are shown on deployment diagram below are in the implementation. The web services are then developed to ensure there is coordination in system by masking a heterogeneity that might exist. The deployment diagram shows all the components of the system and how they interact with each other. The data access object has many methods some of which have been shown in the table below.

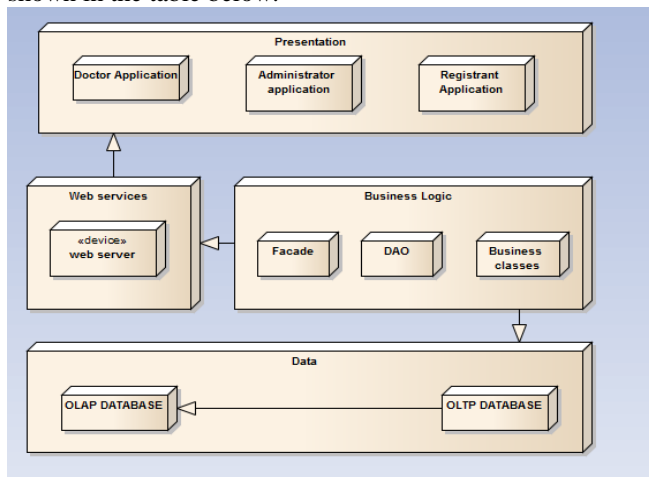


Figure 4 : Deployment Diagram

## Detailed Method Description

| I<br>D | Name                    | Return type     | Arguments                       |
|--------|-------------------------|-----------------|---------------------------------|
| 1      | Authenticate            | User            | String username,String password |
| 2      | retrieveWare House      | WareHouse[]     | No Arguments                    |
| 3      | dropStagingArea         | Void            | No arguments                    |
| 4      | loadToWare House        | Void            | No arguments                    |
| 5      | OLTPTransformD ata      | Void            | No arguments                    |
| 6      | OLTPExtraction          | Void            | No arguments                    |
| 7      | getHealthCentre         | HealthCentre    | String healthCentreID           |
| 8      | updateHealthCentr e     | Void            | HealthCentre HC                 |
| 9      | deactivateHealthC entre | Void            | HealthCentre HC                 |
| 10     | activateHealthCent re   | Void            | HealthCentre HC                 |
| 11     | newHealthCentre         | Void            | HealthCentre HC                 |
| 12     | getListOfHealthCe ntres | HealthCentre[ ] | No arguments                    |
| 13     | getDistricts            | District[]      | No argument                     |
| 14     | getDistrict             | District        | Int districtID                  |

Table 3: list of AdminDao methods

The methods in the table above are critical to the functionality of system and are described below.

- The authentication method accepts a username and password as arguments and checks whether the current user exists or not. If the user exists it returns the user.
- The retrieveWarehouse method retrieves all the data from the warehousedata materialized view and returns an array of the warehouse class
- The method dropStaging area drops the temporal staging area created by the OLTPExtraction method.
- The loadToWarehouse method gets all the data cleaned by the OLTPtransformData method and loads it into the data house
- The OLTPtransformData Method cleans the data from the OLTPExtraction method into the temporal staging area
- The OLTPDataExtraction method goes through all active healthCentres and retrieves data from all the tables in the temporal staging area
- The getHealthCentre method simply gets a particular healthcentre by its ID
- Method updateHealthCentre updates the content of a healthCentre on demand by the admin
- Method deactivateHealthCentre changes the status of a healthcentre to deactivated and drops the database link between nit and that database.
- Method activateHealthcentre changes the status of the healthcentre to activated and create the database link between the databases.
- Method newHealthCentre creates a new healthcentre and assigns it a status of not activated.
- Method getListOfHealthCentres retrieves all the healthcentres in the database and assigns instances of the healthcentre class.



- Method getDistrict retrieves a district by its ID and returns an instance of that district
- Method getDistricts returns all the districts in the database and assigns them to individual instances and loads them into an array.

### AdminFacade

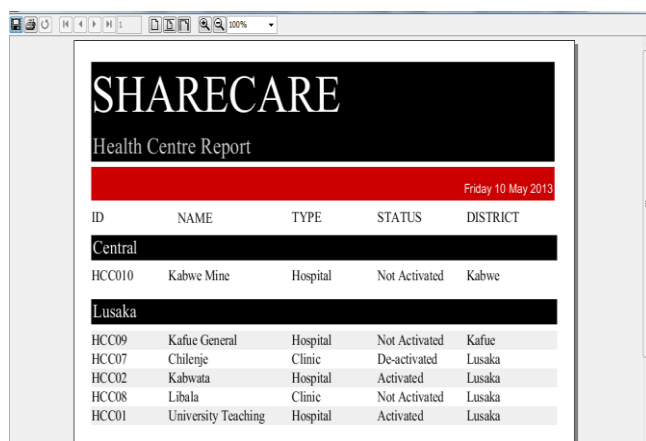
The AdminFacade creates abstraction for the AdminDao. It is created in a separate package and uses the same method name, return type and parameters as the AdminDao.

### Web Services

The development of the web services is achieved using java and the glassfish server version 3+. The URL for the WSDL of the web service is <http://localhost:30199/sharecarews/adminWS?WSDL> the web service class implements all the AdminFacade class methods.

### 3.3 Report Generation

The generation of reports has been achieved in the prototype. Here are examples of some of the reports generated by the program.

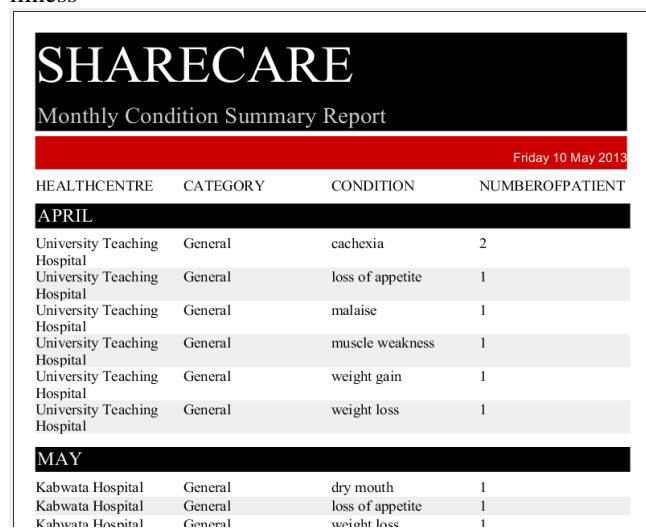


| ID             | NAME                | TYPE     | STATUS        | DISTRICT |
|----------------|---------------------|----------|---------------|----------|
| <b>Central</b> |                     |          |               |          |
| HCC010         | Kabwe Mine          | Hospital | Not Activated | Kabwe    |
| <b>Lusaka</b>  |                     |          |               |          |
| HCC09          | Kafue General       | Hospital | Not Activated | Kafue    |
| HCC07          | Chilenje            | Clinic   | De-activated  | Lusaka   |
| HCC02          | Kabwata             | Hospital | Activated     | Lusaka   |
| HCC08          | Libala              | Clinic   | Not Activated | Lusaka   |
| HCC01          | University Teaching | Hospital | Activated     | Lusaka   |

Figure 5: Health centre summary

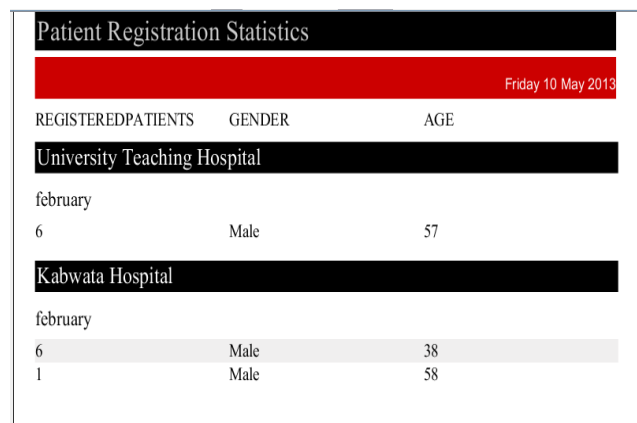
### PatientCondition Summary

This report looks at how many people suffer from a particular illness



| HEALTHCENTRE                 | CATEGORY | CONDITION        | NUMBEROFPATIENT |
|------------------------------|----------|------------------|-----------------|
| <b>APRIL</b>                 |          |                  |                 |
| University Teaching Hospital | General  | cachexia         | 2               |
| University Teaching Hospital | General  | loss of appetite | 1               |
| University Teaching Hospital | General  | malaise          | 1               |
| University Teaching Hospital | General  | muscle weakness  | 1               |
| University Teaching Hospital | General  | weight gain      | 1               |
| University Teaching Hospital | General  | weight loss      | 1               |
| <b>MAY</b>                   |          |                  |                 |
| Kabwata Hospital             | General  | dry mouth        | 1               |
| Kabwata Hospital             | General  | loss of appetite | 1               |
| Kabwata Hospital             | General  | weight loss      | 1               |

Figure: 6 patient condition summary report Patient registration Summary Number of patients that have registered at a health centre

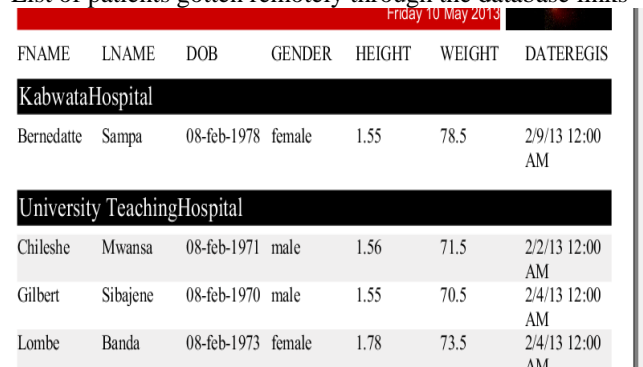


| REGISTEREDPATIENTS                  | GENDER | AGE |
|-------------------------------------|--------|-----|
| <b>University Teaching Hospital</b> |        |     |
| february                            |        |     |
| 6                                   | Male   | 57  |
| <b>Kabwata Hospital</b>             |        |     |
| february                            |        |     |
| 6                                   | Male   | 38  |
| 1                                   | Male   | 58  |

figure 7: patient registration statistics

### Patient list report

List of patients gotten remotely through the database links



| FNAME                              | LNAME    | DOB         | GENDER | HEIGHT | WEIGHT | DATEREGIS       |
|------------------------------------|----------|-------------|--------|--------|--------|-----------------|
| <b>KabwataHospital</b>             |          |             |        |        |        |                 |
| Bernedatte                         | Sampa    | 08-feb-1978 | female | 1.55   | 78.5   | 2/9/13 12:00 AM |
| <b>University TeachingHospital</b> |          |             |        |        |        |                 |
| Chileshe                           | Mwansa   | 08-feb-1971 | male   | 1.56   | 71.5   | 2/9/13 12:00 AM |
| Gilbert                            | Sibajene | 08-feb-1970 | male   | 1.55   | 70.5   | 2/4/13 12:00 AM |
| Lombe                              | Banda    | 08-feb-1973 | female | 1.78   | 73.5   | 2/4/13 12:00 AM |

figure 8: remote patient list

## IV. CONCLUSION

There are several Clinical Data warehouse systems developed to utilize the potential knowledge in clinical data. However, most of the previous work focused on the medical information management[12]. The prototype of Decision Support System described in this paper uses data warehouse as data repository while distributed application designed using the façade design pattern. Some level of analysis has been achieved,ETL tools developed and functioning very well. However there is room for more improvement on the developed system on most modules. ETL processes need to be automatic after set intervals and there is need to implement a module for creating ad hoc queries.

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